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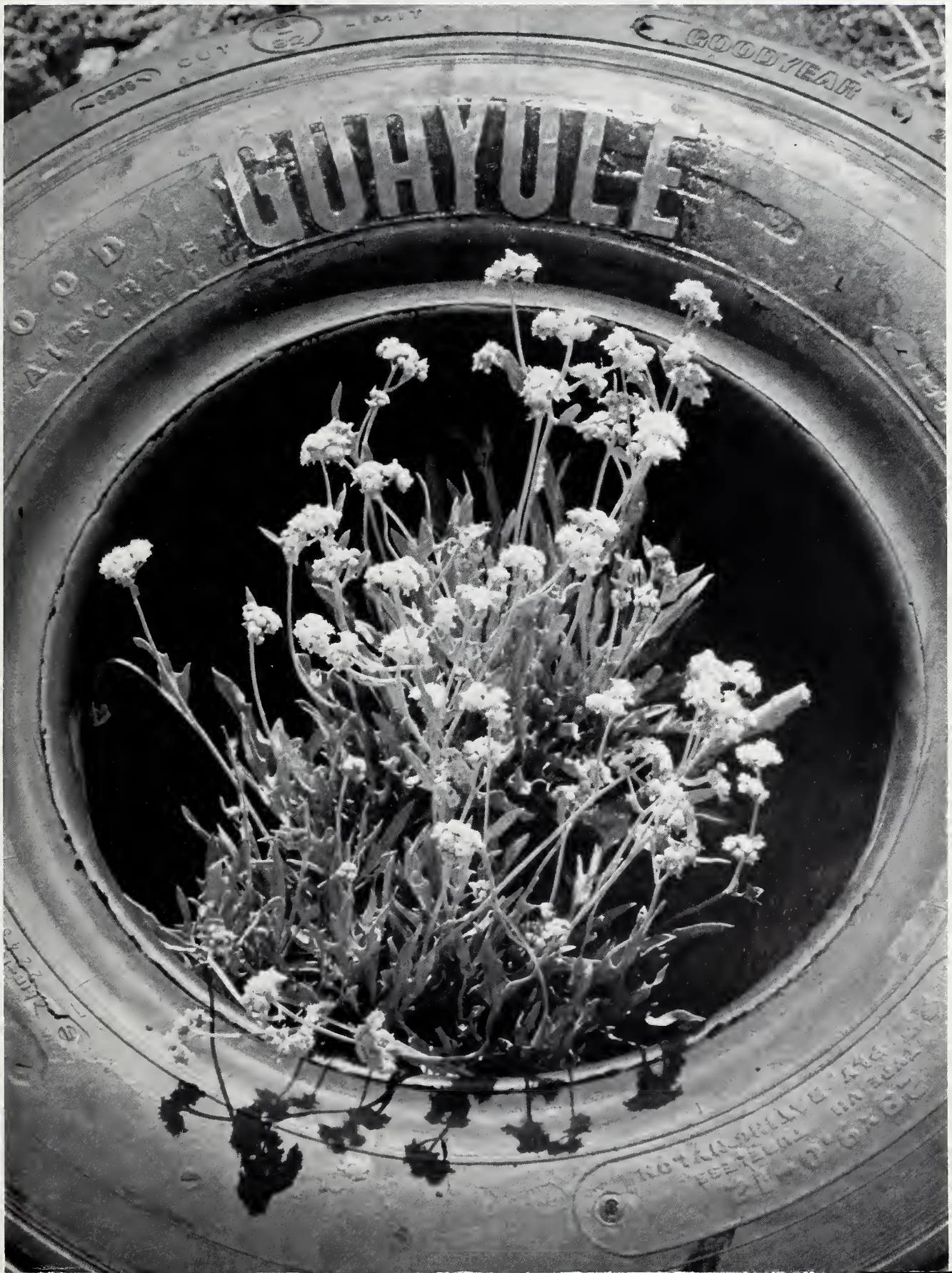

Weed Science: A View of the 21st Century

Historically, the size of the farm was influenced by the number of people available to hoe weeds. Animal power replaced hand hoeing. Then machines and chemicals replaced animals. Today, one farmer with one tractor equipped to apply herbicides can do the work of 40 horses. Modern weed control has permitted mankind to cultivate 10 times more acres than ever before.

The modern era of weed control began with the discovery of the phenoxy herbicide 2,4-D in the early 1940's. Today, we have more than 180 basic herbicides and about 6,000 formulated products. During the past 40 years, weed science has cut crop losses due to weeds in half—from 20 percent to 10 percent. A goal which many believe can be achieved by the 21st century is to reduce these losses to 7 percent or perhaps even lower.

To accomplish this, weed research programs must emphasize new approaches that employ the selective application of stress against weeds while reducing the stress on crops and soils. With a tolerable loss of only 7 percent, we cannot afford to damage the crop.

By expanding the multidisciplinary approach to weed research, we will have a better fundamental understanding of the biology, physiology, genetics, and biochemistry of weeds and their response to control methods. We can then take advantage of chinks in the biological and chemical armor of weeds. At the same time, knowledge of the genetic basis for resistance to herbicides will enable scientists to develop crop plants with more tolerance. Resistance has already been reported in varieties of most crops.

An estimated 1,800 species of weeds cause serious economic losses to crops, livestock, forests, and aquatic resources worldwide. Despite modern technology, about 200 weed species compete with cultivated crops in the United States. This potpourri of weeds with varying periods of germination and highly diverse life cycles obviously cannot be controlled by a single method. It requires an integrated approach that includes cultural, mechanical, biological, ecological, and chemical methods. With this approach, the whole is greater than the sum of its parts.

In the future, weed science will give greater attention to the total farm, area, or region—the agroecosystem—rather than limiting weed control practices to a single crop in a single year. Satellites and other space technology such as lasers will increasingly allow weed scientists to measure weed infestations to better understand and control weed populations.

Herbicides will continue to be a key component of the integrated approach. Two trends characterize current experimental herbicides. First is the trend toward postemergence applications of selective herbicides that control weeds at very low doses (2 to 100 grams per acre) but do not damage crops. Second is the trend toward systemic nonselective herbicides that do not have residual action. The latter are particularly valuable for use in conservation tillage and multiple cropping systems.

One of the new frontiers of weed science is the discovery of untapped biological control agents—insects, mites, pathogens, nematodes, and fish—that attack only the target weed. Sometimes these agents offer the best answer to controlling introduced weeds, especially when a single species infests a large area. Biological agents—primarily insects and plant pathogens—are currently being evaluated for control of nearly 100 species of weeds. They have already completely or substantially controlled 25 to 30 problem weeds such as alligator weed and northern jointvetch.

Controlled-release technology will improve chemical weed control and enhance the use of plant pathogens. Such formulations will dispense short-lived herbicides evenly over the desired period of time. This technology will also lead to safer use of herbicides by reducing herbicide volatility, leaching, drift, and erosion. A new process for encapsulating pathogens or herbicides in nontoxic, water-absorbent gels increases the effectiveness of herbicides, especially in wet soils and in waterways, and holds particular promise with the use of fungi and bacteria.

One area that will see great advance in the future is the study of allelopathy—literally meaning "trouble to each other." Plants produce allelochemicals that inhibit, and sometimes stimulate, the growth of neighboring plants. ARS scientists found that papaya seeds contain a natural toxin that prevents the germination of velvetleaf—a major pest of corn and soybeans—but does not harm the crops. Researchers now envision identifying a wide range of plants that produce toxins to control major weeds.

On the other hand, the chemical strigol, produced by several crops, triggers the germination of witchweed—a noxious invader from Africa. Such natural bioregulators can be used to synchronize germination of dormant weed seeds so that a single herbicide treatment could control a particular weed for years.

Perhaps the single greatest risk involved in chemical weed control is faulty application equipment and misuse. Application technology has not kept pace with herbicide development. Weed scientists now use lasers to precision-tune the droplet size of spray equipment to prevent drift. New application equipment like the rope-wick applicator, recirculating sprayer, and roller wipers apply herbicides directly to the weeds without getting them on the crop. Coating crop seeds with herbicides is an exciting new approach that gives excellent weed control while greatly reducing the amount of chemicals per acre.

We must, in our basic, applied, and developmental research programs, achieve and maintain a fine balance. On the one hand, we must protect our health and comfort and our capacity for producing food and fiber. On the other hand, we must understand the ecological significance of weeds and the methods we must use to control them. Costs, benefits, and risks must be carefully weighed before decisions can be made that are clearly in the public interest. I am confident that we will succeed.

Warren C. Shaw,
ARS National Program Leader,
Weed Science and Agricultural Chemicals Technology

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Cover: A rubber tire encircling the desert shrub—guayule—symbolizes the plant's potential as a primary source of natural rubber for the United States. ARS scientists at six locations around the country are studying guayule varieties, culture, and latex production in concern for national security, should supplies of foreign rubber be interrupted. Story begins on page 5.
0584X711-28

Affecting Photosynthesis with Bioregulators

To increase the amount of rubber in guayule plants, chemist Charles De Benedict of the Pasadena Fruit and Vegetable Chemistry Laboratory sprays bioregulators on the plants. 0584X712-11A

A plant bioregulator that affects photosynthesis may prove to be an important key in meeting world food needs beyond the year 2000.

"It is not just a plant hormone or a growth regulator that increases plant growth alone," says Henry Yokoyama, a chemist and leader of the research team at Pasadena, Calif., making the discovery. "Rather, the new bioregulator appears to increase the efficiency of photosynthesis. Since photosynthesis is common to all green plants, the discovery suggests that the bioregulator would be applicable to a wide range of crop plants."

The bioregulator, having the tongue-twisting initials DCPTA, "has produced dramatic results on such diverse crops as guayule, soybeans, and cotton," says Yokoyama. However, the research is still at the basic stage, he cautions. "We do not understand exactly how all the mechanisms work to produce the results. And much work has yet to be done before it can be recommended as a commercial practice. But," he says, "DCPTA does open some interesting and promising avenues for meeting food needs of a growing world population."

DCPTA is short for 2-diethylaminoethyl-3,4-dichlorophenylether. It is only one of about 250 compounds that Yokoyama and his colleagues have synthesized from commercially available compounds and tested over the past 15 years. They got the idea for DCPTA from their early work using bioregulators to enhance the color of citrus fruits and to increase the rubber content of guayule.

In field tests with soybeans, DCPTA increased protein content by 68 percent, lipid (fat) content by 20 percent, and yield by 35 percent. In greenhouse tests with cotton, it increased the square and boll set by 80 percent.

In earlier studies at Texas A&M University, Yokoyama and university plant scientist C. R. Benedict demonstrated that DCPTA increased the rubber content of the guayule plant about twofold in greenhouse and field tests. According to Yokoyama, results from several avenues of research with DCPTA suggest that it increases plants' ability to convert atmospheric carbon dioxide into usable biochemicals through photosynthesis, resulting in an increase in stored products as well as biomass (yield). "This is the first time that a bioregulator has been discovered that affects both photosynthesis and yield," says Yokoyama.

Past efforts to increase the yield and quality of plants have been through the slow process of selective breeding. Progress was hampered by negative effects: increases in protein content were accompanied by decreases in lipid content, and increases in yield were accompanied by

Guayule—Natural Rubber From the Desert

decreases in both protein and lipid content. Yokoyama attributes these problems to a finite amount of photosynthetic carbon available for synthesis of protein and lipids. The source of carbon had to come at the expense of lipids and other storage materials, he explains. "No such negative effects occurred with use of the bioregulator," Yokoyama emphasizes.

He believes that DCPTA increases photosynthesis by regulating gene expression, that is, the bioregulator turns on genes that either enhance the normal photosynthetic pathway or open a more efficient one. He bases his conclusion on the fact that DCPTA increases a wide range of products in a broad spectrum of plants and does not increase one product at the expense of another. DCPTA does not boost the activity of known plant hormones, he adds.

The concentration and timing of applications are crucial in getting good results. In the soybean tests, the Pasadena researchers applied DCPTA at two concentrations—80 ppm (part per million) and 120 ppm dissolved in water and a wetting agent. The lower concentration produced a more significant overall response, says Yokoyama, noting that the higher concentration increased protein accummulation but did not increase lipid content or yield. He suggests that "a more appropriate range may be at a still lower level with 80 ppm being at the upper end."

DCPTA produced the best results when applied to soybeans at the first-leaf stage and again at the four-leaf stage. When applications were begun after the four-leaf stage, there was no increase in proteins and lipids, and yields increased only slightly. "Apparently, the plant must develop under the influence of DCPTA to exhibit any changes in constituents or yield," Yokoyama says.

The Pasadena researchers tested three other bioregulators on soybeans, but they did not show the same overall increases in protein and lipid content and yield. The research was done in cooperation with Texas A&M University, ARS's Plant Stress and Water Conservation Research, Lubbock, Tex., and the University of California.

Henry Yokoyama is located at the Fruit and Vegetable Chemistry Laboratory, 263 S. Chester Ave., Pasadena, Calif. 91106.
—W. James Whorton, Albany, Calif. ■

During salinity water management studies at the U.S. Salinity Laboratory, Brawley, Calif., research technician Ruben Cordova uses a neutron probe to measure soil moisture in a guayule test plot.
0584X711-20

Thomas A. Edison, Dwight D. Eisenhower, and lately, the U.S. Congress have shared a thread of common interest in a small, drought-tolerant shrub from northern Mexico and southwestern Texas.

Spelled guayule and pronounced "Y-oo-lee," the shrub is known to plant scientists as the most likely source of home-grown natural rubber for the United States.

Although Edison's enthusiasm for guayule (*Parthenium argentatum*) was no doubt largely economic, most later interest has centered around the strategic importance of a domestic source of rubber.

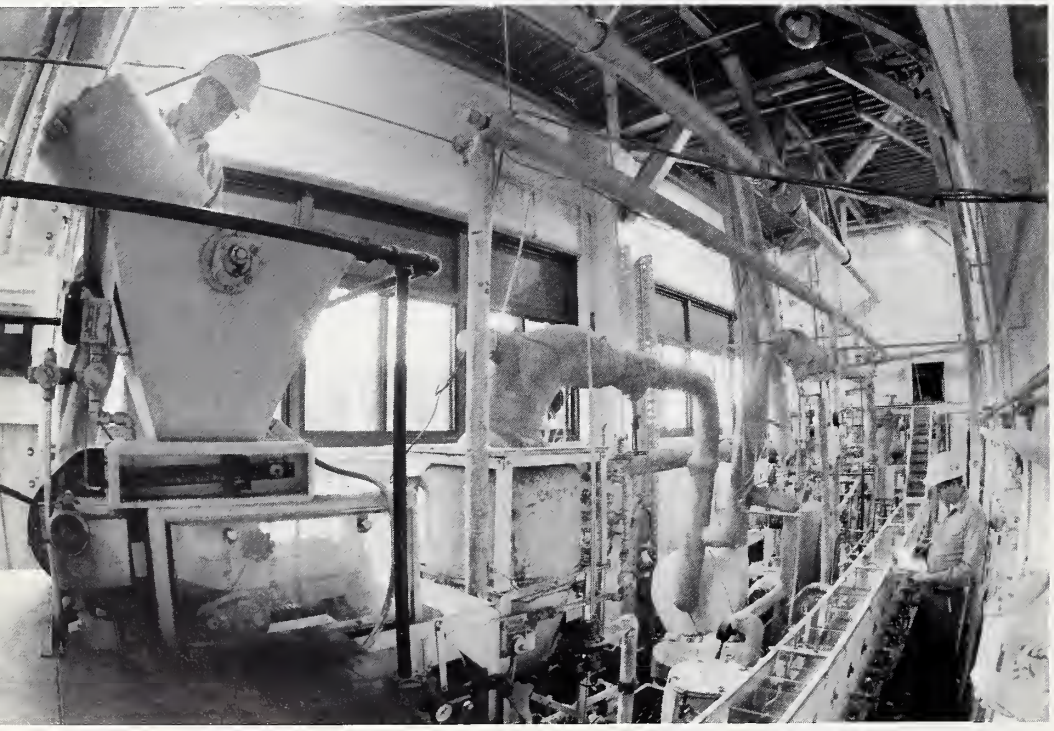
It was this concern for national security, should supplies of rubber be interrupted, that led Congress to pass the Critical Agricultural Materials Act in May 1984.

Dale A. Bucks, national technical advisor on guayule, ARS, says the act both extends and strengthens existing research programs for guayule natural rubber as well as widening the scope of research to include other critical agricultural materials, including certain oils, waxes, and gums.

Guayule research is carried out at six ARS locations as well as being closely coordinated with state agricultural experiment stations of the University of California, Texas A&M University, New Mexico State University, and the University of Arizona.

At Pasadena, Calif., scientists looking for ways to increase rubber content in guayule discovered that bioregulators sprayed on young plants, both in greenhouse and field tests, doubled rubber

Dale Bucks, ARS national technical advisor on guayule, measures guayule plant height while the crop—grown on a marginal soil of more than 95 percent sand—is irrigated by an automated sprinkler system. 0584X707-11



To begin rubber production, technician Robert Brown pours flaked guayule shrub into the NRRC's solvent extractor as mechanical engineer Ronald Montgomery monitors the process. This counter-current system uses the same prinicples employed in commercial extraction plants. 1284X1801-28

Rubber (top) extracted from dried guayule (bottom) at the Northern Regional Research Center (NRRC), Peoria, Ill. Guayule now yields about 5 pounds of rubber per 100 pounds of shrub. However, new selectively bred varieties, improved cultural methods, and growth regulators promise to double rubber field. 1284X1802-3

content in some cases. The bioregulator stimulates production of latex storage cells in plant stems and roots. (See "Affecting Photosynthesis with Bioregulators," p. 4.)

At Beltsville, Md., scientists are studying new methods of direct seeding guayule much like those used for planting small vegetables seeds. Currently, guayule seed germination and survival is extremely poor. Direct field seeding experiments near Phoenix, Ariz., on irri-

'Super Propagule' May Overcome Guayule Problem

"To get guayule 'off the ground' as a dryland crop, you first need to get it out of the ground," says ARS biochemist G. Ram Chandra. The desert shrub's notoriously poor seed germination rate is the subject of Chandra's lament.

Some 2,000 dark brown guayule seeds worth $4 to $5 fit in a single teaspoon. However, Chandra says, neither the small size nor high cost are serious stumbling blocks.

The real problem facing scientists seeking ways to seed directly in desert or semidesert areas is overcoming problems inherent in guayule seed, he says.

gated land and near Weslaco, Tex., under dryland conditions are showing promising results.

At Phoenix, Ariz., scientists are identifying climate and soil requirements of guayule. Rubber yield will be related to water use and plant water stress. Recent findings indicate that established plants can survive with only 8 inches of rainfall a year, but highest yields require at least 36 inches of natural precipitation and irrigation water. Researchers at Phoenix stress that although more water means greater rubber yields, guayule offers a great deal of flexibility in when and how much water is applied. With improved crop management practices, scientists now believe guayule can be completely or partially harvested earlier than the 3 to 5 years previous studies indicated.

At Riverside and Brawley, Calif., and Weslaco, Tex., scientists are investigating guayule's tolerance to soil salinity. They have found that some seedling varieties are extremely sensitive to salt, while others show moderate tolerance. Most mature plants can tolerate irrigation water containing up to 3,800 parts per million of salt—more than four times saltier than Colorado River water. Varieties even more salt tolerant are being selected. Moderate salt tolerance means that irrigation drainage water from other crops may be reused or that less productive land may be suitable for guayule.

Also at Weslaco, scientists are developing cultural and fertilization techniques for guayule production on lands that aren't or can't be irrigated. Guayule and buffel grass are being interplanted in test plots. The buffel provides forage for cattle while guayule plants become a living storehouse for future rubber supplies.

At Peoria, Ill., scientists have developed an analytical method that uses relatively inexpensive equipment to quickly determine rubber content in plants. A solvent extraction process has been modified to remove more than 80 percent of the rubber in freshly harvested or dried guayule shrubs. Researchers are also conducting evaluation studies on rubber quality and possible uses for plant material left after the rubber is extracted.

Guayule passes a tire-scorching test against natural rubber at 145 miles per hour in simulated carrier landings at the Patuxent Naval Air Test Center in Maryland. 0684W917-12A

Dale A. Bucks is located at the U.S. Water Conservation Laboratory, 4331 E. Broadway Rd., Phoenix, Ariz. 85040 — **Dennis Senft,** Berkeley, Calif. ■

Natural seed lacks vigor. Untreated seed is typically sown directly onto the soil surface where, vulnerable to wind, only a few percent germinate.

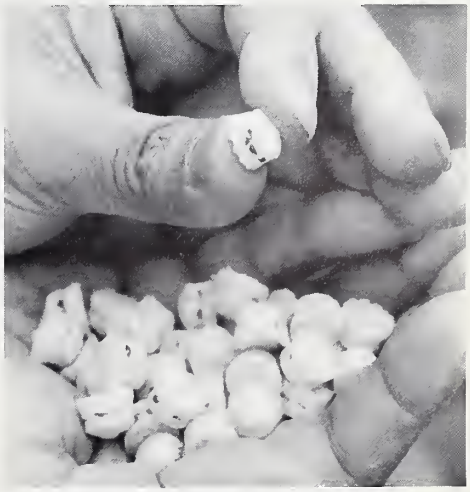
Too few take root in the field to guarantee commercial potential to the crop, says Chandra. To date, successful guayule stands have resulted only after seedlings were transplanted from nurseries to fields. The practice is workable for high-value crops such as tomatoes or sweet potatoes, but cost-prohibitive for guayule.

Guided by studies on guayule seed physiology, Chandra and co-workers in the Seed Research Laboratory, Beltsville, Md., are trying to create a 'super-propagule'—a chemically treated guayule seed in a sand-gelatin pellet. The pellets anchor seed into the ground while the chemical treatment helps break dormancy. Field establishment has increased by 50 percent with this treatment.

At Chandra's laboratory, the seed is coated with polyethylene glycol solution, growth promoters, and regulators to start the seed growing while fungicides and lime protect and prepare seedbed environment.

Use of gelatin pellets permit scientists and seedmen to "add everything that is known to help weak seeds" such as guayule to succeed, says Chandra. "Pellets may make direct seeding of guayule a commercial possibility."

G. Ram Chandra is located at the Seed Research Laboratory, Bldg. 006, Beltsville Agricultural Research Center-West, Beltsville, Md. 20705—**Stephen Berberich**, Beltsville, Md. ■


Chemically treated guayule seeds in sand-gelatin pellets. Pelletizing makes mechanical seeding commercially practical. 0584X587-30A

Polyunsaturated Fats Lower Blood Pressure

Physiologist Marta Van Loan (background) monitors treadmill exercises while lab technician Patrick Mayclin records body fat content of a volunteer in a water displacement tank. The rise of the water level in the tank reflects the volunteer's weight and corresponding percentage of body fat. 0783X850-15A

Nutrition research is verifying the axiom: We are what we eat.

A silent killer lurks in 1 out of every 5 Americans over the age of 25, and stalks many more. It is hypertension—chronic high blood pressure—and it increases the risk of heart attack and stroke. Victims feel little or no ill effects until severe headaches, chest pains, shortness of breath, or heart palpitations send them to a doctor. The usual prescription: stop smoking, lose weight, take daily medication, and reduce salt intake.

Nutrition researchers recognize that the relationships between diet and blood pressure are far more complex than the amount of salt in the diet, and they are piecing this puzzle together. Recent findings indicate that hypertension stems from too little of other substances in the diet. Ultimately, researchers hope to replace treatment with scientifically based diet recommendations to prevent high blood pressure and the other major risk factors to cardiovascular disease—high blood cholesterol levels and an increased tendency for the blood to clot spontaneously in the vessels.

Polyunsaturated Fats vs. Saturated Fats

A series of nutrition studies in the United States, Finland, and Italy suggests that one of the important factors affecting blood pressure is the amount of polyunsaturated fats in the diet.

According to James M. Iacono, director of the Western Human Nutrition Research Center (WHNRC), San Francisco, Calif., Americans typically consume 3 to 4 percent of their total calories as polyunsaturated fats, while saturated fats account for 4.5 times that amount. "We're finding that you have to consume 6 to 7 percent polyunsaturated fats to lower blood pressure," he says.

By increasing the ratio of polyunsaturated to saturated fats, Iacono says: "We significantly reduced both systolic and diastolic blood pressure in 40- to 60-year-old men and women with normal or slightly elevated blood pressure. And, we did this in the last two studies without reducing their intake of meat, dairy products or eggs." The researchers also maintained salt intake at prestudy levels.

Iacono points out that blood pressure can be reduced simply by increasing polyunsaturated fats in the diet, regardless of the saturated fat content. But the experimental diets were designed to reduce cholesterol at the same time.

Iacono and chemist Rita M. Dougherty have coordinated eight diet intervention studies since 1974 to determine if risk factors for cardiovascular disease could be reduced by altering the intake of fat. They also aimed to design diets that were practical to prepare and did not differ radically from customary menus. They accomplished both goals.

In all but one study, the volunteers lived at home and either ate meals prepared by the researchers or prepared their own meals using polyunsaturated products supplied by the researchers. "We bought our food at local supermarkets," Iacono emphasizes.

After conducting two studies at Beltsville, Md., the researchers turned to populations in eastern Finland and southern Italy because they represented the extremes in cardiovascular disease. The Finns have the highest death rate related to cardiovascular disease in the world and are among those who consume the highest amount of saturated fats—about 20 percent of total calories—says Dougherty. However, she adds, as word of the studies spreads, many Finns are changing their eating habits. The Italians, on the other hand, are lowest in both categories with saturated fats accounting for about 9 percent of total calories. Saturated fat calories outnumber polyunsaturated nearly 5 to 1 in the typical diet of eastern Finland and only 2 to 1 in the typical diet of southern Italy. (Southern Italian diets are high in olive oil—a monounsaturated fat—which appears to have no effect on risk factors.) Americans fall between the two populations in all categories.

In the U.S. and Finnish studies, the researchers maintained volunteers on the same number of calories they customarily

Van Loan (right) jogs with a volunteer at the WHNRC. To maintain good health during their 100-day "confinement" for dietary studies, volunteers are encouraged to exercise regularly. 0783X852-9

Meals for nutrition studies at the WHNRC are carefully planned by head dietition Alice Fong. 0783X845-6A

consumed, but reduced the fat calories in the modified diet by about 15 percent (from approximately 40 percent of total calories to 25 percent) and balanced polyunsaturated with saturated fats—P/S = 1.

As expected, reducing total fat calories significantly reduced blood cholesterol levels. In one Finnish study, the average reduction in blood cholesterol was 23 percent—from 260 milligrams per deciliter to 200—during a 6-week period. A long-term study recently completed by the National Heart, Lung, and Blood Institute, NIH, confirmed that reducing cholesterol levels reduces the chances of heart attack.

Increasing polyunsaturates in the diet improved the other two major risk factors—blood pressure and clotting time. "We can consistently bring mild hypertensives back to normal," says Iacono. In some cases, the reduction in blood pressure was dramatic, he notes. "One volunteer went from a high of 150/120 to 126/90 in just 30 days."

During one of the studies in Finland, the researchers compared the effect of a low-sodium diet with the low-fat, high-P/S diet. Volunteers on the low-fat, high-P/S diet had dramatic reductions in blood pressure, whereas those on the low-sodium diet had only slight reductions in blood pressure. Iacono contends that the level of salt in the typical American diet (8 to 12 grams per day) does not affect the blood pressure of people with normal kidney function if they consume enough polyunsaturates.

Blood tests done during the studies support the findings of other researchers that a higher intake of polyunsaturated fats reduces the tendency of the blood to clot spontaneously. This reduces odds for

Comparison of low-fat, high-P/S diet (left) with a high-fat, low-P/S diet. The following menus are selected from 10 daily menus used in studies at Beltsville, Md., and San Francisco, Calif. The low-fat menus provide an average cholesterol content of 300 milligrams or less per day.

	25% total fat, P/S = 1.0	**42% total fat, P/S = 0.25**
BREAKFAST:	Orange juice Cornflakes with skim milk White toast Canned peaches	Orange juice French toast (egg, whole milk, white bread) with powdered sugar topping
LUNCH:	Broiled beef pattie on hamburger roll, catsup, mustard Oven browned french fries Lima beans Carrot, celery sticks on lettuce leaf Sugar cookies	Broiled beef pattie on hamburger roll, catsup, mustard Oven browned french fries Carrot, celery sticks on lettuce leaf Sugar cookies
DINNER:	Poached chicken breast (skinless) Whipped potatoes Green beans Tossed salad (lettuce, celery, cucumber) with French dressing Whole wheat bread Apple	Oven fried chicken breast (with skin, enriched flour, butter, oil) Whipped potatoes Green beans Tossed salad (lettuce, celery, cucumber) with French dressing Apple
BREAKFAST:	Orange juice Cheerios with skim milk Grapes White toast	Orange juice Med. boiled egg Sausage White toast
LUNCH:	Roast turkey (skinless) Boiled potatoes with paprika Green peas Carrot, celery sticks Dinner roll Orange sherbet	Roast turkey with gravy Boiled potatoes with paprika Carrot, celery sticks Dinner oll Pumpkin pie
DINNER:	Vermicelli with sauce (tomato puree, garlic powder, parmesan cheese) Tossed salad (lettuce, celery, cucumber) with corn oil, vinegar dressing French bread Apple	Vermicelli with sauce (tomato puree, garlic powder, parmesan cheese) Meatballs (butter, oil) Tossed salad (lettuce, celery, cucumber) with olive oil, vinegar dressing French bread Pound cake
BREAKFAST:	Orange juice Egg omelette Cornflakes with skim milk White toast Angel food cake	Orange juice Egg omelette Bacon slices White toast
LUNCH:	Baked chicken breast (skinless) Rice Mixed vegetables Salad (sliced tomato, cucumber, lettuce leaf) White bread Pineapple	Baked chicken breast (with skin) Rice Mixed vegetables Salad (sliced tomato, cucumber, lettuce leaf) with mayonnaise White bread Pineapple with shredded coconut
DINNER:	Roast pork Baked potato Wax beans Lettuce wedge with French dressing Dinner roll	Roast pork Baked potato with sour cream Wax beans Lettuce wedge with French dressing Apple
	Available with every meal: Soft margarine, jelly, sugar, salt, skim milk, and coffee or tea	Butter, half & half, sugar, salt, whole milk, and coffee or tea

thrombosis. Blood clots can block coronary arteries to cause heart attack, brain arteries to cause stroke, or major arteries in the lung to deprive all the organs of oxygen.

"The quantity of fat and the quality of fat have to be distinguished," says Iacono. The amount of saturated fat affects blood cholesterol levels, while the intake of polyunsaturated fats affects blood pressure and clotting time as well as blood cholesterol. Virtually all of the polyunsaturates in food today, he explains, are comprised of the fatty acid linoleic acid, which the body requires to manufacture prostaglandins. Prostaglandins regulate blood clotting, increase muscle tone in the blood vessels, and regulate blood pressure through the kidneys. The kidneys excrete excess water and salts, thereby reducing pressure "in the pipeline."

Learning to Substitute

To reduce fat calories and increase polyunsaturates in the eight studies, the researchers used lean meats with all visible fat trimmed off before cooking, including removing chicken skin; substituted skim milk and low-fat cheese for whole milk and high-fat cheese; and substituted polyunsaturated products for butter, mayonnaise, salad dressings, and cooking oils. (See sample diets.)

Palm and coconut oils are high in saturated fats, says Iacono, while corn oil and soybean oil are high in polyunsaturates. Cheeses, other than the low-fat types such as cottage cheese and mozzarella made from skim milk, contain between 30 and 60 percent saturated fat, he notes. And some baked products such as crackers and cookies contain hard or saturated fats to increase shelf life.

According to Alice Fong, head dietician at WHNRC, "the label is a good guide" for selecting polyunsaturated products. Those interested in trying the diet should be careful in choosing foods, she says, but should not avoid a particular food because it may contribute important nutrients—proteins, vitamins, major minerals, and trace elements. "There's nothing wrong with having an occasional burger and french fries," she notes, "provided the beef is very lean and the potatoes are fried in highly polyun-

saturated oil, then well drained." One should also choose the accompanying foods wisely.

Fong says she uses fresh fruits and vegetables, bread, cereals, pasta, and potatoes in the experimental diets to make up for the reduction in fat calories. Because a gram of pure fat supplies more than twice the calories of a gram of pure carbohydrate, the modified diet has a lot more bulk, she explains. According to Pirjo Pietinen, a cooperating Finnish scientist, the added vegetables, fruit, berries, and fish in the experimental diet remarkably improved its vitamin and mineral content. Low vitamin and mineral concentration, she writes, "is one of the major concerns" about the Western diets—characterized by a high content of refined foods.

Iacono contends that the modified diet is easy to stay on, but Fong suggests that people will have to change their eating habits: "They have to learn how to substitute." The advantages are clear, however. When the volunteers resumed their normal diets during the "switchback" phase of the studies, blood cholesterol and blood pressure generally returned to prestudy levels, says Dougherty. Some of the volunteers had a hard time returning to the high-fat diet, she says.

The study in southern Italy clinched the findings. Here the researchers reversed the experimental diet to increase total fat calories and decrease the ratio of polyunsaturated to saturated fats. Predictably, blood cholesterol levels and blood pressure rose significantly.

The American Heart Association recommends a diet containing 30 percent total fat calories with 10 percent as polyunsaturates and equal amounts as monounsaturates and saturated fats. "We're finding that recommendation quite good," says Iacono.

In the comprehensive studies, he and Dougherty worked with scientists at Georgetown University, Washington, D.C., Finland's National Public Health Institute, the University of Helsinki, Italy's National Institute of Nutrition, and the University of Milan.

James M. Iacono and Rita M. Dougherty are located at the Western Human Nutrition Research Center, P.O. Box 29997, Presidio of San Francisco, Calif. 94129. —**Judy McBride,** Beltsville, Md. ■

Potassium, Blood Pressure Linked

Potassium's role in controlling blood pressure has been suspected for more than two decades. Now a year-long study at the Beltsville Human Nutrition Research Center has added more evidence for a link between potassium and blood pressure—at least among males. The study also suggests that Americans are eating nearly twice the amount of sodium they should in relation to their potassium intake and thus may be increasing their chances of high blood pressure.

Sixteen women and 12 men participated in the study, which was designed to gather accurate, long-term information about calorie and nutrient consumption among "free-living" subjects who were selecting their own diets. The study was coordinated by ARS nutritionist June L. Kelsay and carried out by a team of 15 scientists from the Beltsville center and the University of Maryland during 1981 and 1982.

Janet T. Holbrook, a faculty research assistant with the University of Maryland who works at the Beltsville center, discovered the potassium connection while computer-analyzing diet and blood pressure records for the volunteers. She found that the males experienced a noticeable reduction in systolic blood pressure and an increase in the amount of sodium excreted whenever they increased their potassium intake above their long-term averages. Women in the study, however, did not show a similar effect. Variations in hormone levels may have caused changes in blood pressure which obscured changes related to potassium, says Holbrook.

Holbrook says she searched for a relationship between the two minerals by comparing each person's weekly potassium intake during the week before a blood pressure measurement with their own yearly averages for potassium and blood pressure. "When the men's potassium intake was up, blood pressure was the lowest," she says.

Total potassium intake averaged 3.3 grams per day for the men and 2.3 grams for the women—both well within the "safe" limits of 1.9 to 5.6 grams per day for adults, according to James C. Smith, Jr., a chemist and chief of the Vitamin and Mineral Nutrition Laboratory at Beltsville. "But," he says, "the ratio of sodium to potassium was higher than it should be."

The volunteers consumed as much as 1.2 grams of sodium for each gram of potassium. The Food and Nutrition Board of the National Academy of Sciences recommends 0.6 grams of sodium for each gram of potassium as "safe and adequate."

Some nutritionists believe the ratio of sodium to other minerals such as potassium may be a key factor controlling blood pressure, Smith says.

Most foods contain some potassium, says Holbrook, but fresh fruit and vegetables are among the best sources. Cooking, particularly boiling, often removes part of the potassium. She cautions against taking potassium supplements without a doctor's advice, however, because too much of it can be harmful.

James C. Smith and Janet T. Holbrook are located at the Beltsville Human Nutrition Research Center, Vitamin and Mineral Nutrition Laboratory, Bldg. 307, Beltsville, Md. 20705.—**Lloyd McLaughlin,** Beltsville, Md. ■

Sludge—A Resource Whose Time Has Come

"Municipal sludge is a natural resource, not just a disposal problem," says Robert H. Dowdy, soil scientist and sewage sludge researcher. "The most valuable attribute of sludge may be its high level of organic matter."

C. Edward Clapp, soil biochemist on the ARS research team at St. Paul, Minn., agrees with Dowdy. "In sandy soils, organic matter increases the soil's ability to hold water. In heavy clay soils, it opens up the soil to allow air and water to enter."

Agricultural application of sewage sludge offers an energy saving and productive means of waste disposal, returning the materials to a natural cycle, which can be productive and beneficial, Dowdy says.

The need to process more than 50 billion cubic yards of liquid effluent and more than 10 million tons of dry sludge in the United States every day has forced sewage officials, sanitary engineers, and wastewater treatment plant operators to look beyond the conventional burn and landfill systems of disposal. More rigid water and air quality standards have also increased the demand for alternative disposal methods, Dowdy says.

What is sludge in addition to the organic matter? Dowdy says sludge produced in the United States each year contains amounts equal to 2.5 percent of the total nitrogen, 6 percent of the phosphorus, and 0.5 percent of the potassium applied on U.S. farms each year.

Though composition of sewage sludge varies greatly, these median figures, based on sludge samples collected from 200 different sources in eight states, offer some indication of content: organic carbon, 30 percent; total nitrogen, 3.3; total phosphorus, 2.3; total sulfur, 1.1; calcium, 3.9; iron, 1.1; aluminum, 0.4; sodium, 0.2; potassium, 0.3; magnesium, 0.4.

In 10 years of experiments, Dowdy and his ARS and University of Minnesota colleagues found sludge supplied all the nitrogen and phosphorus that crops could use, but additional potassium was needed. They successfully grew corn, potatoes, green beans, and other vegetables, as well as turfgrasses.

In one 3-year experiment, Clapp reported that annual applications of 4.5 tons of sewage sludge per acre produced yields of 108 bushels of corn and 4.3 tons of reed canarygrass per acre. Conventional fertilizer treatments produced 102 bushels of corn and 3.4 tons of canarygrass.

"We had 10 treatment areas for this project, 5 in corn and 5 in reed canarygrass. One area of each crop received a normal application of commercial fertilizer, the others received sludge applications. Analyses showed no difference in the heavy metal content of the corn grain or leaf tissue from the sludge areas as compared with corn from the fertilized plots," Clapp said. "The reed canarygrass tissue analyses were also normal for good quality grass and showed no significant differences between sludge and control areas."

Surface water samples were collected during runoff, and soil water samples were taken at depths of 2 feet and 5 feet. Samples from wells and from other sources outside the plot area were also collected and analyzed for heavy metal concentrations and plant nutrients.

"The concentration of heavy metals in soil water was not increased by this rate of sludge application, and analyses of surface and subsurface water showed no movement of potentially polluting materials out of the watershed," Clapp says. "There was some movement of sludge-supplied plant nutrients in surface water during snowmelt, early spring runoff, and high rainfall periods."

The watershed is terraced and designed to keep runoff on the treatment areas. Results indicate that sludge may be used safely for agricultural purposes if the land is properly terraced for control of runoff, Clapp says.

In general, the contents of sludge, if applied at the rate plants normally use nutrients, are either beneficial or harmless to plants. Most public concern is with the trace metals, lead, mercury, cadmium, nickel, zinc, and copper. Dowdy says lead and mercury normally found in sewage sludge are not available for plant uptake, so the researchers studied the other four.

Zinc, nickel, and copper are not a problem in animal or human food, because plants will stop growing before they can accumulate enough metal to be harmful to animals or people consuming them. The fourth metal, cadmium, is the most critical because, some medical researchers say, cadmium intake may relate to such problems as kidney damage, hypertension, and heart and circulatory problems."

Cadmium is taken up by plants, especially under acid soil conditions, and concentrates mainly in the leaf and stem tissue. Even with high cadmium levels in the soil, other plant parts such as seeds, fruits, and roots would be relatively safe to eat.

"The worst case I can imagine would be to use sludge from an industrial source high in cadmium to grow lettuce, chard, or collards in containers where plant roots have only sludge for nutrients. But even then, if the sludge is alkaline rather than acid, cadmium taken up by the plants would be limited," Dowdy says.

To evaluate the effects of high cadmium feed on livestock, the researchers compared corn silage treated with commercial fertilizer and silage grown on land receiving annual application as high as 20 tons of high cadmium (up to 150 ppm) sludge an acre.

"The highest rate of sludge application produced silage containing 5.26 ppm of cadmium, more than 10 times the amount recommended by the National Research Council as the upper limit in animal feed," Dowdy says.

They fed the silage to lambs for 100 days, until lambs reached market weight, and to dairy goats for 3 years. They tested the milk, blood, and organ tissue for cadmium concentrations and checked the animals for growth and health over the time of the feeding tests.

Dowdy says 90 percent of the goat's ration was silage. Cadmium concentrations in goat's milk, which averaged 0.01 ppm before the test, did not increase as a result of eating corn silage containing high levels of cadmium.

However, Dowdy says, cadmium concentration did increase in the kidney and liver tissue of both goats and lambs. After 3 years of feeding, the highest cadmium concentration in kidney tissue

samples from goats was 22.4 ppm. The highest reading for lambs, fed 100 days, was 18.9 ppm. No physical damage to the organs was observed in either animal.

Goats fed silage grown under normal commercial fertilization applications had cadmium levels of 3.1 ppm in their kidneys. Lambs had 2.1 ppm.

With dairy goats, feed intake and efficiency and milk production were not reduced in the studies, Dowdy says. Lambs fed to slaughter weight on sludge-fertilized corn silage had slightly higher rates of gain than lambs receiving silage grown on regular commercial fertilizer. Feed intake rates were about the same for both sludge and non-sludge-treated silage.

Soil acidity is the major soil characteristic that affects trace metal uptake by growing plants, Dowdy says. "We found that the zinc content of barley seedlings rose from 22 ppm to 50 ppm with increased rates of sludge application on an acid soil (pH 5.9) but increased only slightly on an alkaline soil (pH 7.9).

"Our research shows that, where soil acidity is maintained at a pH value of about 6.5, only a very small percentage of sludge-borne metals will be absorbed by a given crop and they will not leach into groundwater," he adds.

Application on any site will probably be limited by the eventual buildup of metals although the long-term effects of trace metals added to soils are not yet clear, Dowdy says.

Before sludge is used for agricultural purposes it should be analyzed for fertilizer and heavy metal content. Usually, if applications of sludge are limited to the nitrogen demands of plants, heavy metals should not be a problem, he says.

Potential users should contact the state agency responsible for waste disposal and ask about sludge sources and regulations. Usually the source institution can provide information concerning metal and nutrient content of its sludge.

Robert H. Dowdy and C. Edward Clapp are located at the ARS Soil and Water Management Research Unit, University of Minnesota, St. Paul, Minn. 55108.—**Raymond Pierce**, Peoria, Ill. ■

An ARS soil scientist checks the spray pattern of sludge shot from a travelling gun irrigator designed to handle agricultural wastes containing up to 10 percent solid matter. A half-inch layer of sludge is applied, after which scientists trace its heavy metal, nitrogen, and phosphorus components. 0777W871-17A

Composted Sludge Gains Favor

A favorite method of turning plant material into organic matter for the garden is rapidly being embraced by municipal sewage districts as a practical way to treat millions of tons of sludge produced daily in the United States. The method is composting, but scaled-up enormously from the traditional backyard pile of leaves.

Most negative aspects of sewage sludge can be overcome with composting, says George B. Willson, agricultural engineer with the Biological Wastes Management and Organic Resources Laboratory, Beltsville, Md. Weed seeds and human pathogens are killed by the heat generated during composting. The process even degrades some organic chemicals present in sludge, although the heavy metal content is not altered, he says.

In aerated pile composting which was pioneered in 1973 at Beltsville, Willson says, wet sludge is mixed with approximately three times its volume of wood chips. The woodchip-sludge mixture is then piled about 8 feet deep over perforated pipes which supply air to the composting material. After about 3 weeks of composting, the material is air dried and the wood chips screened out for reuse. The composted sludge, now nearly odor free, is allowed to "cure" for another month before it is sold.

Since pilot-scale treatment ended at Beltsville in 1982, Willson has closely followed composting's growth across the country. At last count in mid-1983, composting was being used at 61 locations ranging in size from Los Angeles County to some very small National Park Service sites. Another 29 treatment facilities were under construction or in the design stage.—**Lloyd McLaughlin,** Beltsville, Md. ■

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Patents

PATENTS is a regular feature of *Agricultural Research* magazine. Its purpose is to make the more than 1,200 patented inventions of the U.S. Department of Agriculture better known to businesses and individuals that might benefit from using them.

If you are interested in applying to obtain the license on a patent, write to the following address for an application form and information on license provisions and license responsibilities: Patents Office, USDA-ARS, Office of the Administrator, Rm. 323, Bldg. 003, Beltsville Agricultural Research Center-West, Beltsville, Md. 20705.

Potent Cancer Inhibitor Found in Plant Seeds

A novel alkaloid compound isolated from the seeds of a toxic weed has proved exceptionally potent against lymphocytic leukemia in National Cancer Institute tests with mice and was effective in controlling human tumor cells in culture in the Institute's assays.

The alkaloid is structurally related to certain cyclic antibiotics produced by bacteria, but it is unique among plant products. It is named sesbanimide, after the plant genus *Sesbania,* some members of which are toxic to poultry and livestock along the Southern Coastal Plain of the United States. (See *Agricultural Research,* May 1983, p.4)

Sesbanimide is of interest to pharmaceutical companies involved in developing anticancer agents.

For further technical information, contact Richard G. Powell, Northern Regional Research Center, 1815 N. University, Peoria, Ill. 61604. **Patent Application Serial No. 06/566,469, "Sesbanimide and the Use Thereof in Treating Leukemia Tumors."**

Removing Fruit the Gentle Way

A novel apparatus consisting of rubber-tipped metal rods with built-in safety releases gently pushes mature fruit from narrow canopies, leaving immature fruit behind and trees undamaged.

The apparatus is designed for harvesting T- and V-shaped fruit canopies and yields fresh market-quality fruit. It can be operated manually or as the prime component of a mobile mechanical harvester and fruit-catching machine. (See *Agricultural Research,* Nov/Dec 1983, p. 14.)

Manufacturers of small farm and orchard equipment will be interested in this versatile fruit remover.

For further technical information, contact Donald L. Peterson, Appalachian Fruit Research Station, Rt. 2, Box 45, Kearneysville, W. Va. 25430. **Patent No. 4,377,064, "Rod Press Fruit Remover."**

Fuel From the Farm for Diesel Engines

Diesel engines can now be powered by farm products because of a significant improvement in combining crude vegetable oils with simple alcohols such as methanol or ethanol. The new mixtures are stable at temperatures as low as −10°C (+14°F) when the water content does not exceed 1 percent.

Vegetable oil pressed from soybeans, corn, rapeseed, sesame, or cottonseed is preferred, but other crops could be substituted. The alcohol—which thins the oil to improve combustion and reduce gumming—is dispersed in the oil as a microemulsion by means of a single, noncorrosive additive. The result is an economically attractive vegetable-oil-based fuel that lends itself to on-the-farm blending.

Both the farm sector and the petrochemical industry should be interested in this and previous patents for vegetable oil-based fuel. A worldwide market exists for such inventions, particularly in those countries with limited sources of petroleum.

For further technical information, contact Arthur W. Schwab, Northern Regional Research Center, 1815 N. University, Peoria, Ill. 61604. **Patent Application Serial No. 06/638/826, "Microemulsions from Vegetable Oil and Lower Alcohol With Octanol Surfactant as Alternative Fuel for Diesel Engines," and the related Patent Application Serial No. 432,402 and Patent No. 4,451,267.**

Protecting Cereal Grains From Deterioration

Grinding or cracking grains activates inherent enzymes that rapidly cause a bitter or rancid flavor, but methods to solve the problem have either changed the physical properties of flours or substantially reduced their nutritional value and yield.

A new method to inactivate these enzymes in all common cereal grains renders flours with the same physical and nutritional properties and the same yield as freshly milled whole grain flours. Treated grains or their milled products can be stored much longer without flavor deterioration.

The invention—a heat treatment of the whole grain—is simple, economical, and commercially attractive, especially for small grains that cannot easily be degerminated.

For further technical information, contact George N. Bookwalter, Northern Regional Research Center, 1815 N. University, Peoria, Ill. 61604. **Patent Application Serial No. 06/635,945, "Process for Stabilizing Whole Cereal Grains."**